NASA-CR-200881

FINAL TECHNICAL REPORT

FOR NASA GRANT NCC-3-229

Entitled

NUMERICAL INVESTIGATION OF CHEMICALLY REACTING TURBULENT FLOWS FOR SPACE PROPULSION

Prepared for

NASA Lewis Research Center
Cleveland, Ohio 44135

by

Principal Investigator:

Kenneth J. De Witt
Distinguished University Professor
Department of Chemical Engineering
The University of Toledo
Toledo, Ohio 43606

Submitted APRIL, 1996
for the period
9-1-91 to 2-12-96

FINAL REPORT for NCC 3-229

The work done under this grant from NASA Lewis began in September, 1991, and was completed in February, 1996. The grant was used to support the research performed by Dr. Sang-Wook Kim, a Post-Doctoral Research Associate at the University of Toledo. Dr. Kim's work was performed under my direction and involved computational fluid mechanics codes for both transitional and steady turbulent flows and for flows with chemical reactions.

From 9-1-91 to 12-31-92, the grant was entitled "Low Reynolds Number Multiple-Time Scale Turbulence Model and Its Application to Unsteady and Transitional Turbulent Flows", and from 1-1-93 to 2-12-96, the title was "Numerical Investigation of Chemically Reacting Turbulent Flows for Space Propulsion". The title change was made to more clearly reflect the work of Dr. Kim.

The attached list of publications resulting from this work are all available in the open literature, and comprise the final report for this grant. All of these publications have previously been submitted to the grant technical monitor.

List of publications

(a) Journal Articles

1. S.-W, Kim, "Numerical investigation of chemical reaction - turbulence interaction in compressible shear layers" *Combustion & Flame,* vol. 101, pp. 197-208, 1995.

2. S.-W, Kim, K.B.M.Q. Zaman and J. Panda, "Numerical investigation of unsteady transitional flow over oscillating airfoil" *ASME J. Fluid Engineering,* vol. 117, pp. 10-16, 1995.

3. S.-W. Kim and T. J. Benson, "Fluid flow of a row of jets in crossflow: A numerical study," AIAA Journal , vol. 31, no. 5, pp. 806-811, 1993.

4. S.-W. Kim and T. J. Benson, "Calculation of a circular jet in crossflow with a multiple-time-scale turbulence model," International Journal of Heat and Mass Transfer, vol. 35, no. 10, pp. 2357-2365, 1992.

5. S.-W. Kim and T. J. Benson, "Comparison of SMAC, PISO, and iterative time-advancing schemes for unsteady flows," Computers and Fluids, vol. 21, no. 3, pp. 435-454, 1992.

(b) Refereed Conference Papers

1. S.-W, Kim, "Numerical investigation of the influence of chemical reaction on turbulence field," To be presented in the AIAA 32nd Aerospace Sciences Meeting, Reno, Nevada, January, 1994.

2. S.-W, Kim, K.B.M.Q. Zaman and J. Panda, "Calculation of unsteady transitional flow over oscillating airfoil" in Separated Flows, eds. J. C. Dutton and L. P. Purtell, ASME FED-vol. 149, pp. 165-176, The Fluid Engineering Conference, Washington, DC, June 20-24, 1993.

3. S.-W. Kim, "Low Re multiple-time-scale turbulence model and calculations of steady and pulsating shear layers" in Fluids Engineering, ed. R. Bajura, ASME FED-vol. 133, pp. 181-182, The Fluid Engineering Conference, Los Angeles, California, June 21-26, 1992.

4. S.-W. Kim and T. J. Benson, "Fluid flow of a row of jets in crossflow - A numerical study," AIAA paper 92-0534, The 30th AIAA Aerospace Sciences Meeting, Reno, Nevada, January 6-9, 1992.

(c) Contractor Reports

1. S.-W. Kim, "Low Re multiple-time-scale turbulence model and calculations of steady and pulsating shear layers," NASA CR-189176, 1992.